Characterization of High Performance Electric Motor

Joseph Martinez

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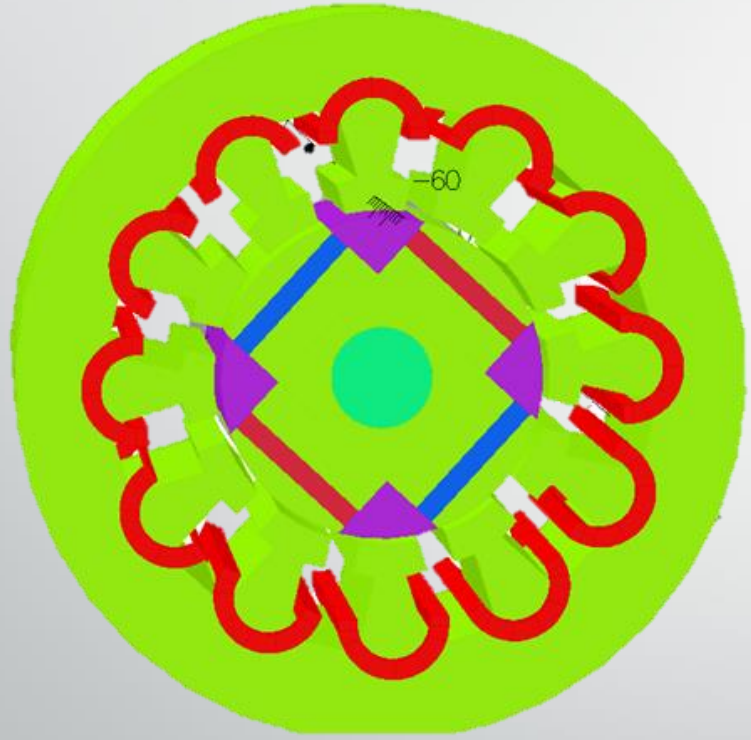
- California State University, San Bernardino
- Year: Senior
- Major: Physics
- Branch: RT-Vehicle integration and test
- Mentor: Kurt Kloesel and Yohan Lin

Overview

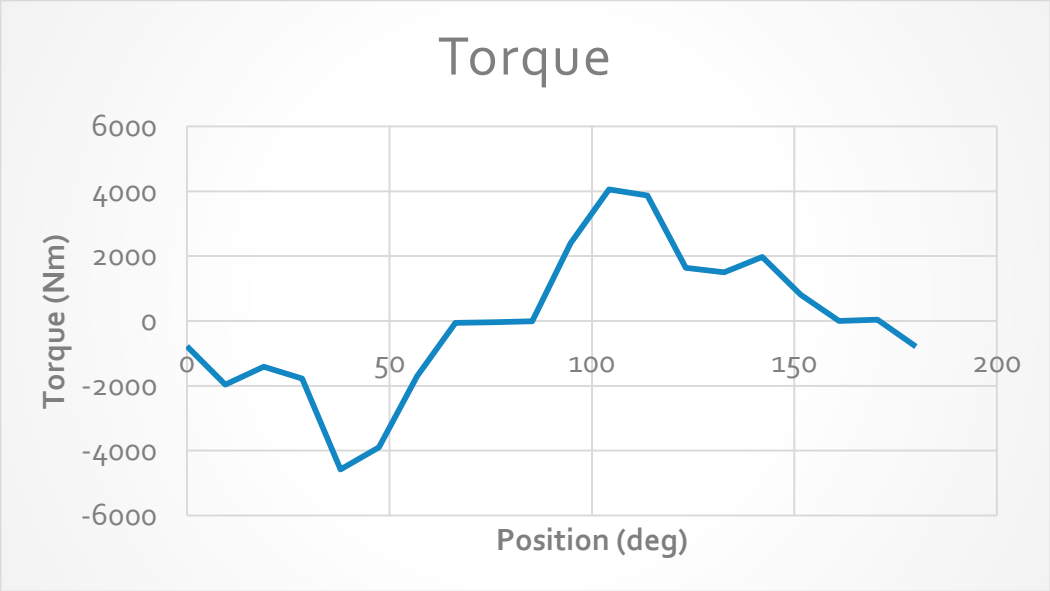
- Modeling and characterizing 15 kW Electric motor
- Designing variations of currently used motors
- 3D modeling and printing of small adaptor
- Electric motor control of sensorless electric motors

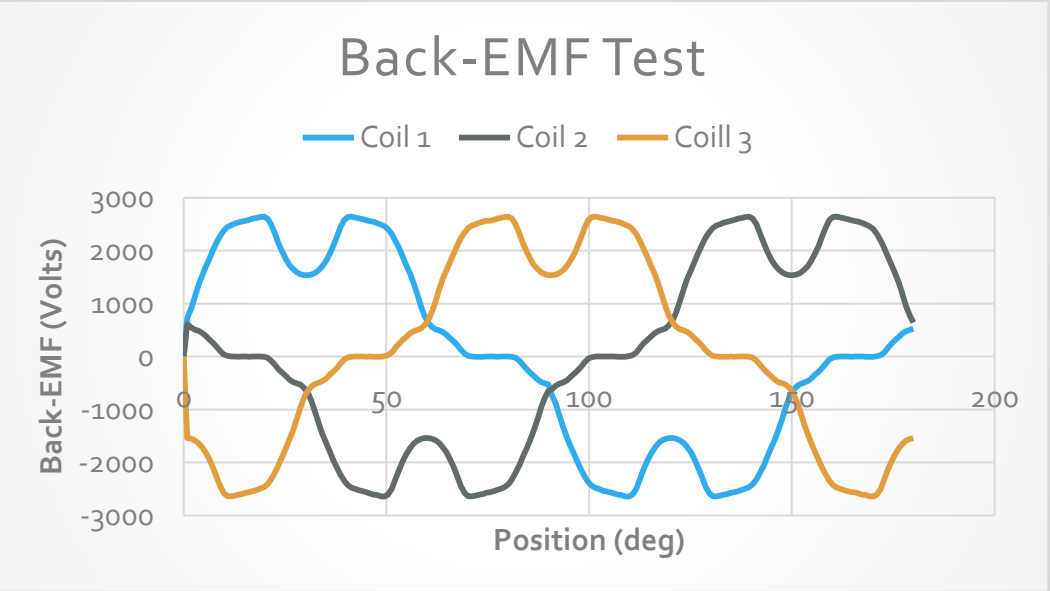
Permanent Magnet Synchronous Motors (PMSM)



- Use magnets in the rotor
- More reliable because there is no need for brushes
- Has a sinusoidal back electromotive force
- Modeled and simulated using Opera 3D

Expected data of PMSM

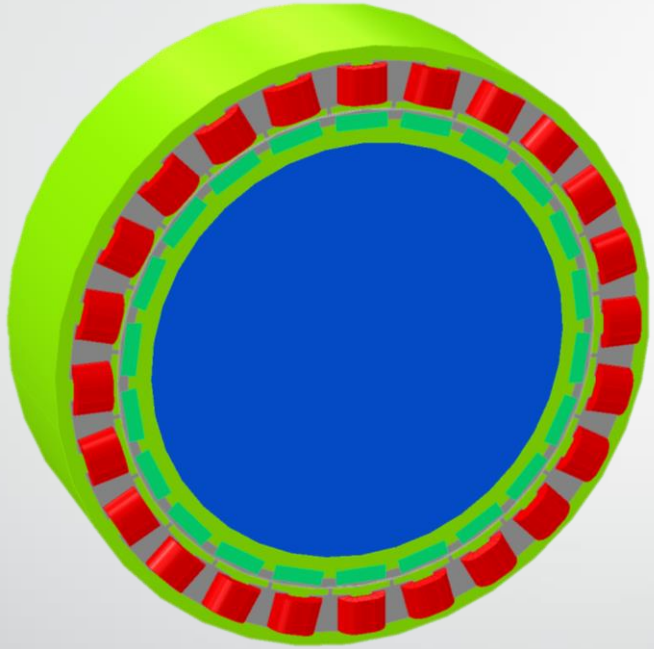


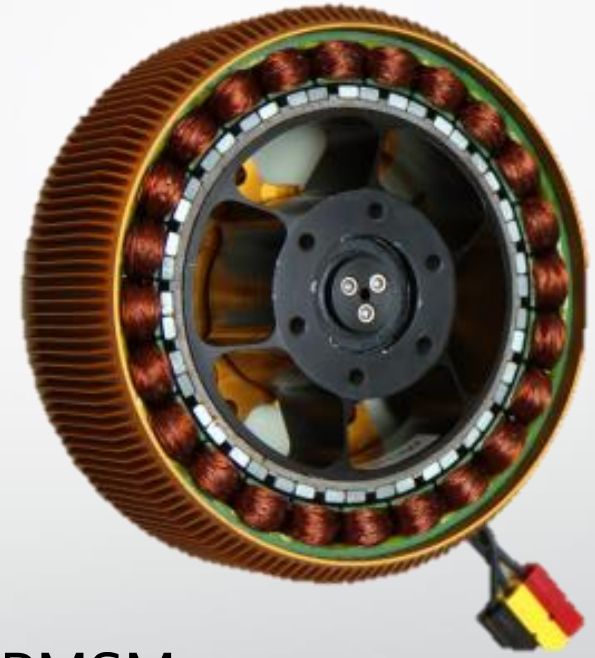


- The Torque from a single coil
- Motor is ran to always be at highest torque

- Back-EMF is like a natural break
- Can deduce RPM form it

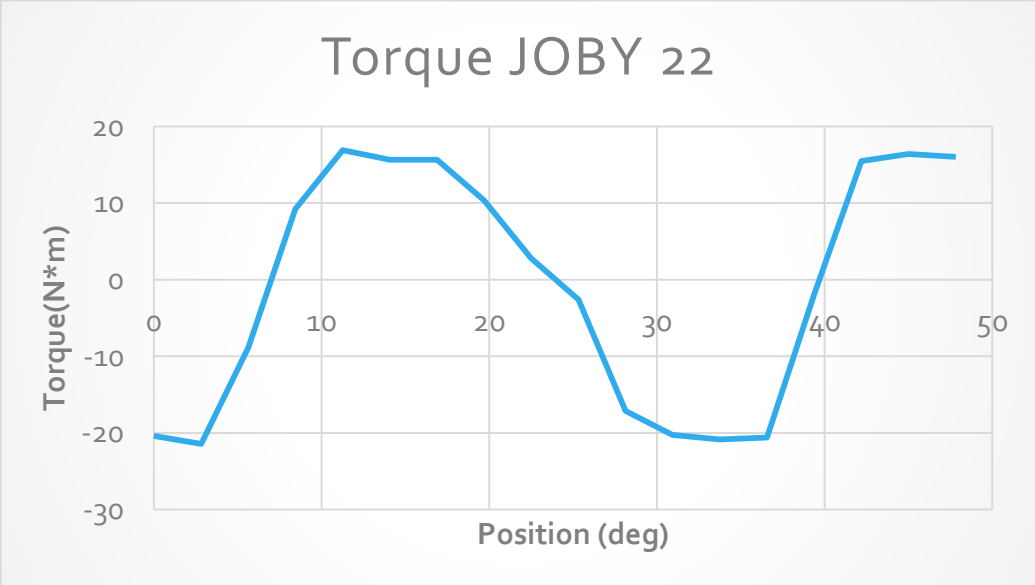
Joby 22 pole electric motor

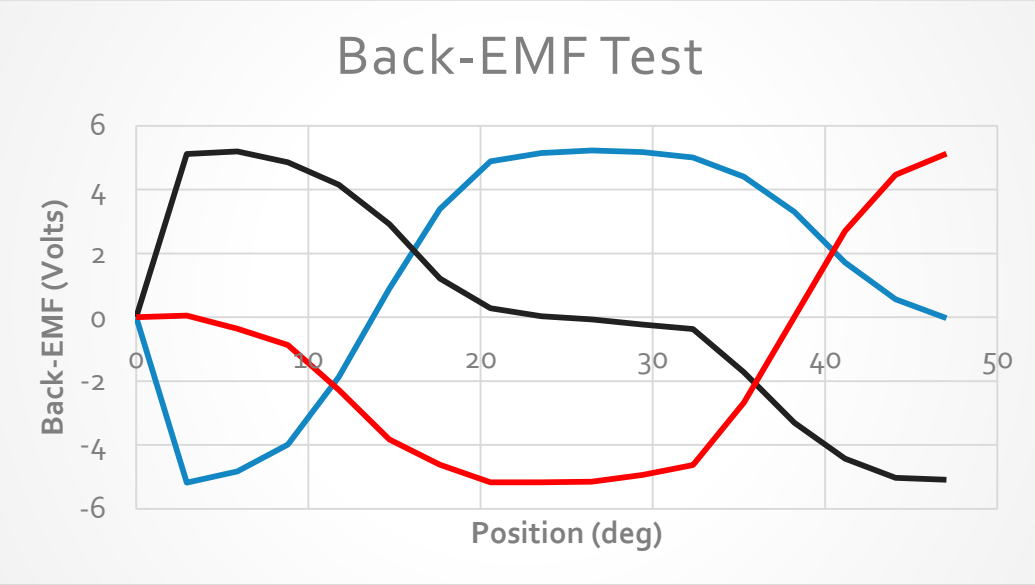




- 22 pole PMSM
- Nominal speed:6000 RPM
- Continuous torque:13N×m

Characterization of JOBY 22 motor (Nominal RPM)

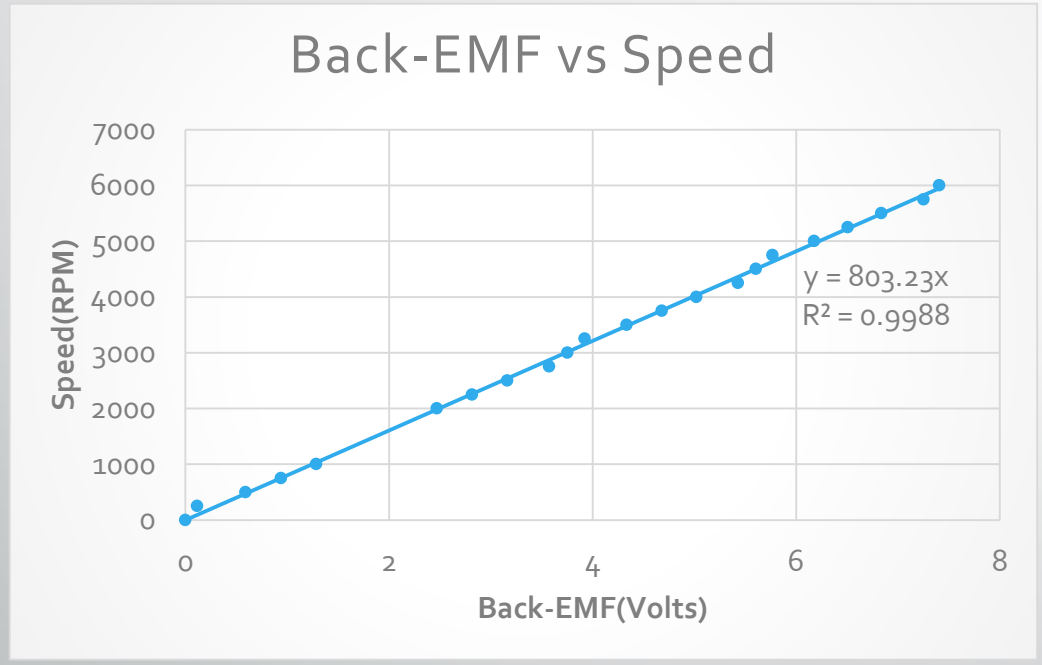




- Torque ~15N*m (Expected 13N*m)
- Good First order approximation
  - Ignores elements like eddy currents

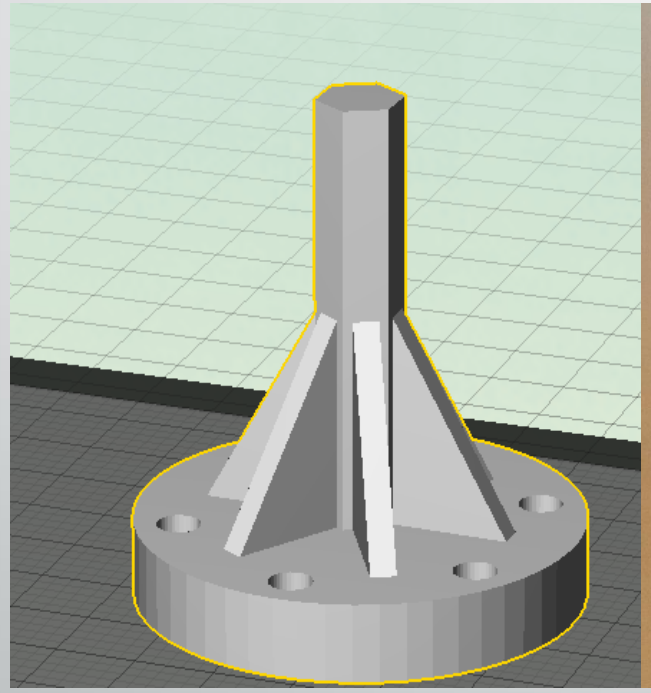
- Back-EMF ~sinusoidal
- 120 degrees
- RMS value of 3.75 Volts

Back-EMF to obtain speed



- Allows speed to be rated without use of sensors
- Very Linear trend
- The deviations get smaller as the speed gets higher

Verifying Results



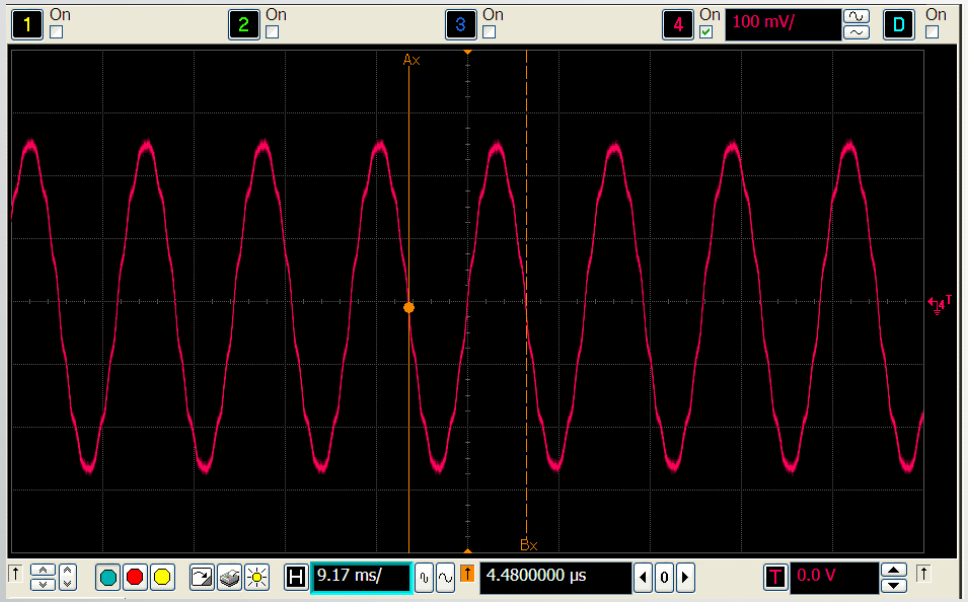
3D Printed adaptor

- Used as a drill attachment
  - Run motor as a generator
  - Gives us ability to find back-EMF

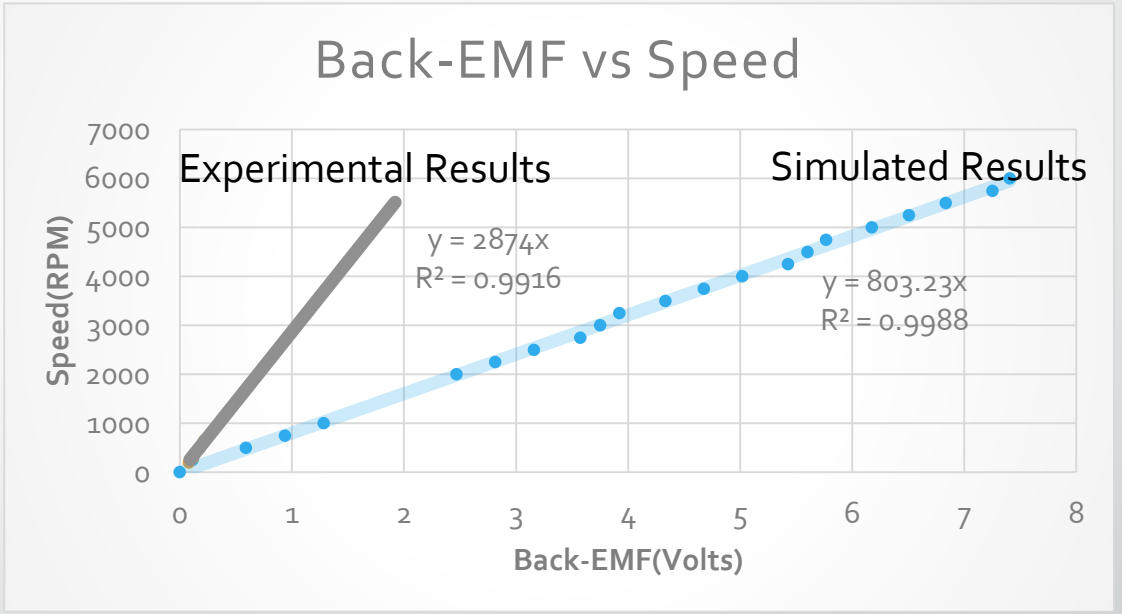
- Created using Solidworks
  With the help of Troy Kuhns and Tommy Pestolesi

- Printed using Makerbot

Verifying Results



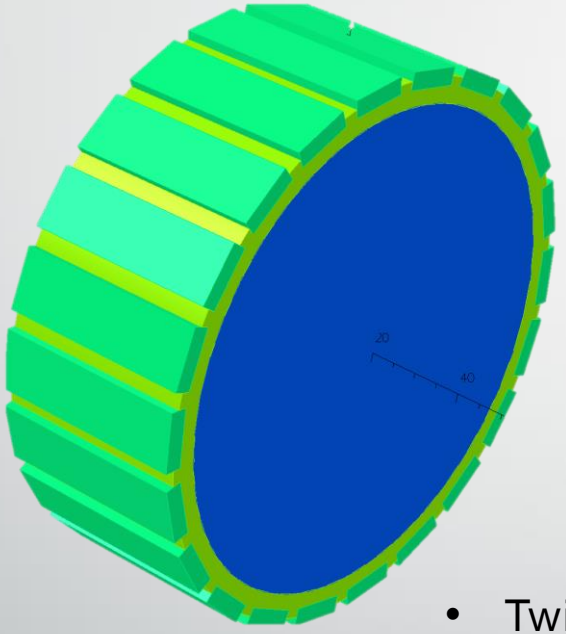
- Sine wave
- Amplitude grows when speed is increased
- Wavelength Decreases as speed increases



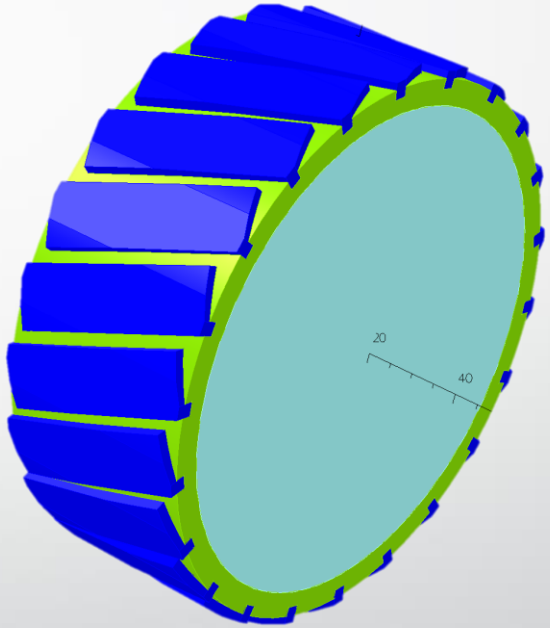
- Slope of experimental Data is much greater than Simulated results
- Could be due to incorrect modeling
  - Magnets too weak
  - Higher resistance in the coil

Adding a Twist

Normal Rotor



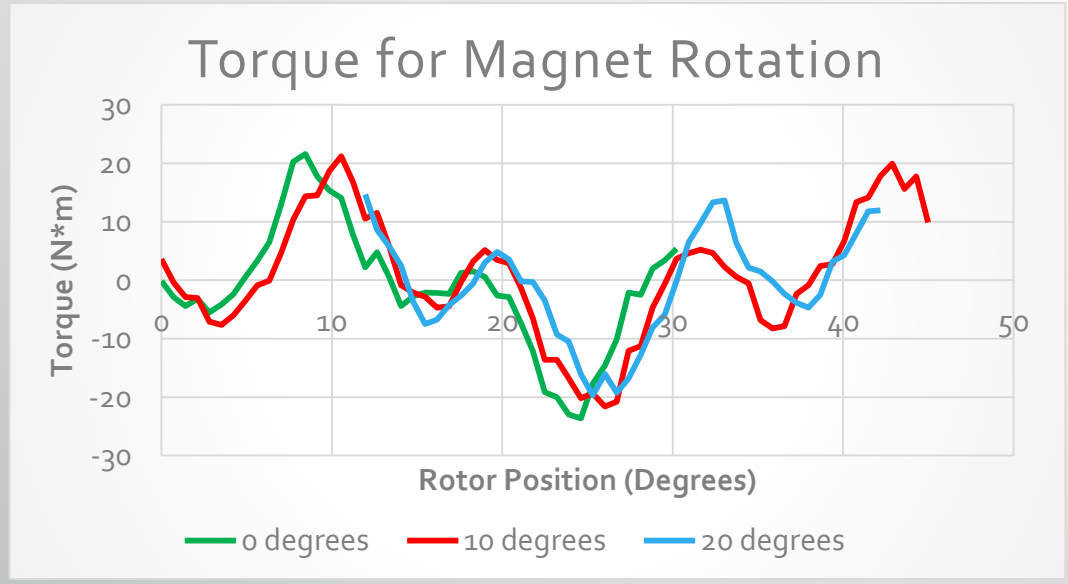
Twisted Rotor (20 degrees)



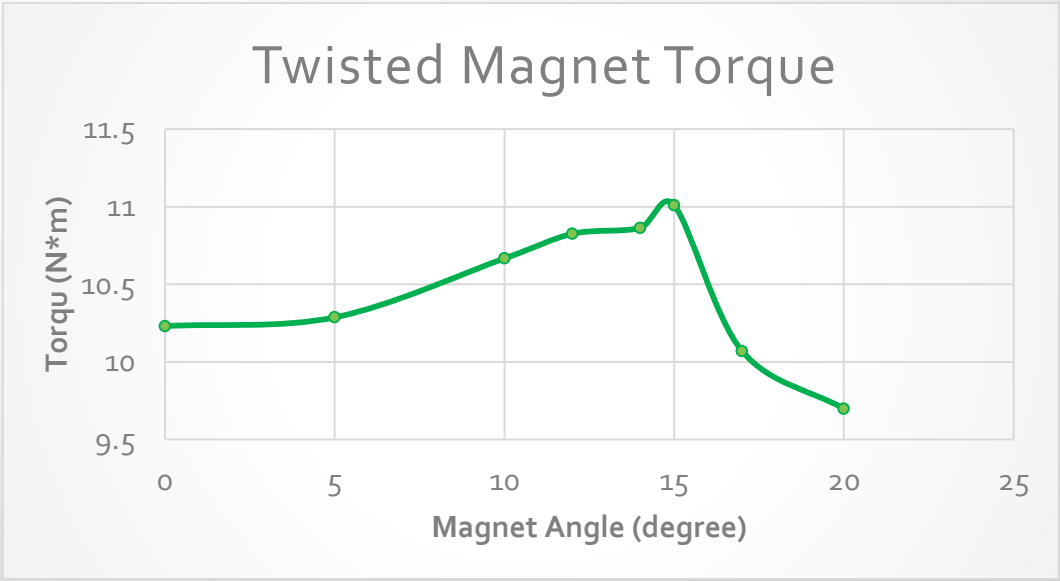
- Twisting the magnets in the rotor
- Normal peaks at about 16 N*m
- Fairly common in electric motors

How the angles compare

Torque

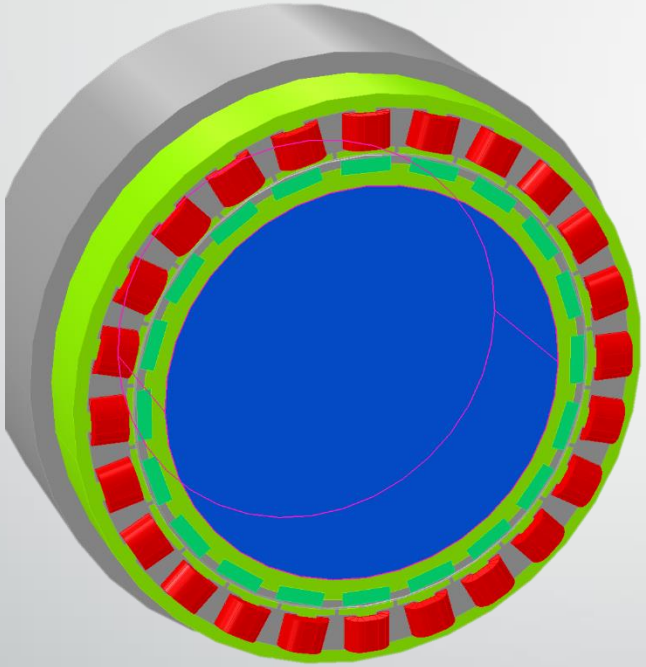


Torque RMS



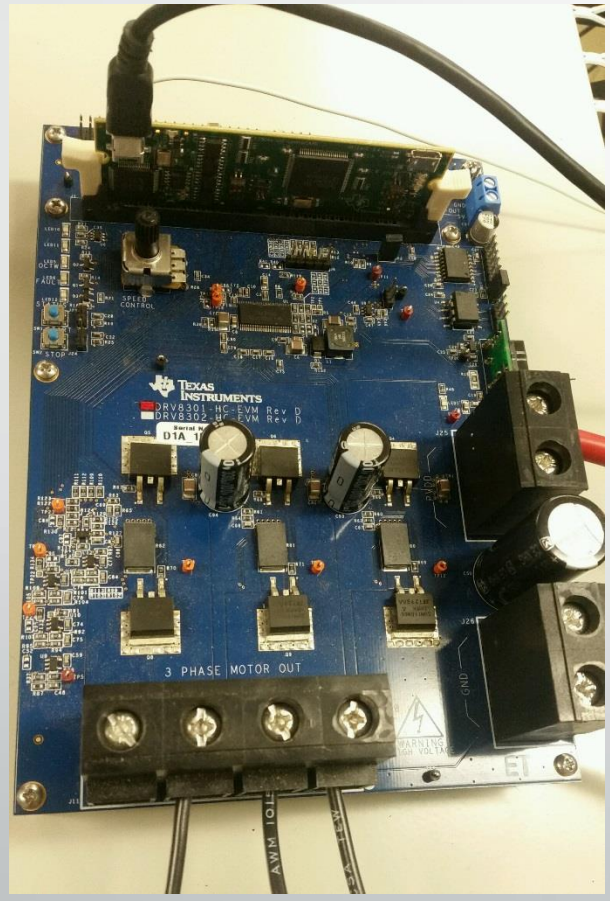
- Shape of the curve is roughly the same
- RMS looks like it peaks around 15 degrees
  - Only ~0.7 N*m of a difference

JOBY 20



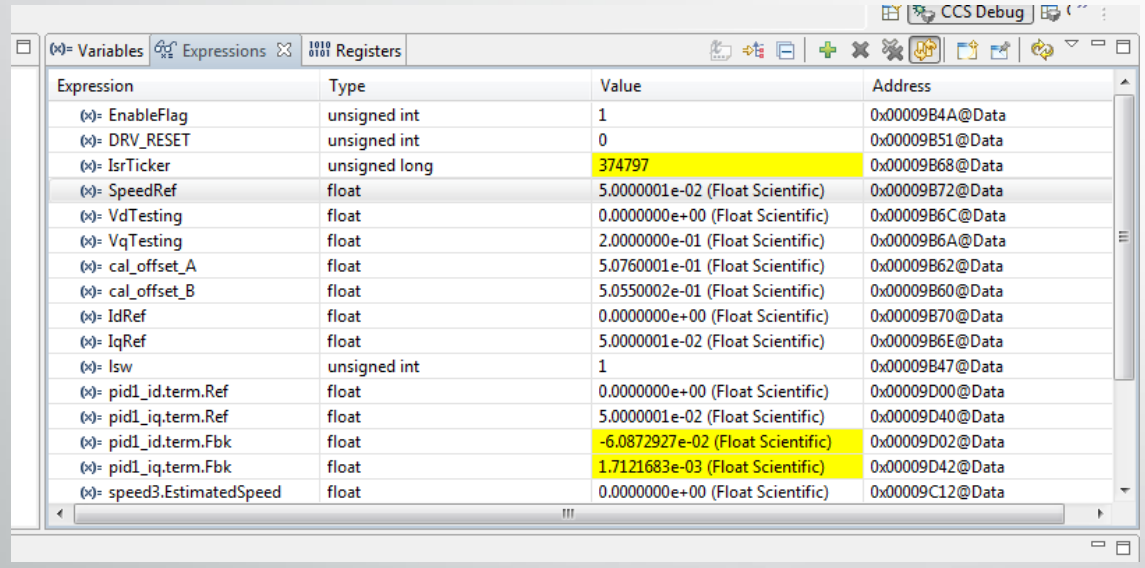
- 15 kW electric PM motor
- Motor used in the IronBird
- Never got it to simulate correctly
  - Probably due to incorrect symmetry arguments

Motor Control Board



- Texas Instruments Board DRV8301
- Used to drive large motors
  - Able to get Joby 20 pole up to ~2000 RPM
- Produces a 3-Phase signal

Running the motor with the TI software

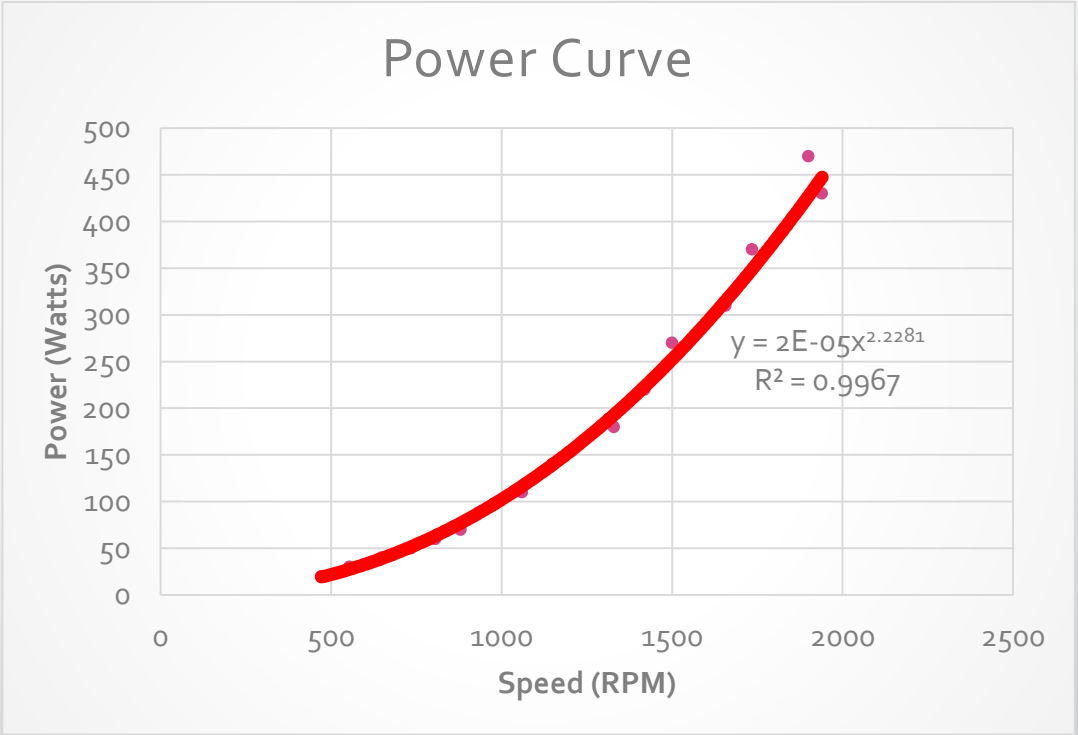


Expression	Type	Value	Address
EnableFlag	unsigned int	1	0x00009B4A@Data
DRV_RESET	unsigned int	0	0x00009B51@Data
IsrTicker	unsigned long	374797	0x00009B68@Data
SpeedRef	float	5.0000001e-02 (Float Scientific)	0x00009B72@Data
VdTesting	float	0.0000000e+00 (Float Scientific)	0x00009B6C@Data
VqTesting	float	2.0000000e-01 (Float Scientific)	0x00009B6A@Data
cal_offset_A	float	5.0760001e-01 (Float Scientific)	0x00009B62@Data
cal_offset_B	float	5.0550002e-01 (Float Scientific)	0x00009B60@Data
IdRef	float	0.0000000e+00 (Float Scientific)	0x00009B70@Data
IqRef	float	5.0000001e-02 (Float Scientific)	0x00009B6E@Data
Isw	unsigned int	1	0x00009B47@Data
pid1_id.term.Ref	float	0.0000000e+00 (Float Scientific)	0x00009D00@Data
pid1_iq.term.Ref	float	5.0000001e-02 (Float Scientific)	0x00009D40@Data
pid1_id.term.Fbk	float	-6.0872927e-02 (Float Scientific)	0x00009D02@Data
pid1_iq.term.Fbk	float	1.7121683e-03 (Float Scientific)	0x00009D42@Data
speed3.EstimatedSpeed	float	0.0000000e+00 (Float Scientific)	0x00009C12@Data

Watch window

- TI Code Composer Studio
- Manipulate variables to get desired response from the motor
  - Control speed, torque, current, voltage depending on which program
- Yellow highlights changing variables

Running the motor



- Ran to about 2000RPM
- Able to control speed and gather data
- Power curve should be an x^3 Relationship

Future works

- Correct the 20 pole motor
- Figure out what is wrong with the back-EMF in Joby models
- Further investigate twisted angles
- Get the TI controller to do closed loop motor control

Thanks!

- Becky Flick
- Kurt Kloesel-Mentor
- Yohan Lin-Mentor
- Michael Butros
- NASA- CIPAIR Award # NNX11AQ99G
- KARATE Squad!

Questions?